Remote Sensing and Environmental Research at Ural State University (AIRS CH_4)

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Directions and Some Results

General directions of research

- ***Development of forward models and software for IR radiative transfer in cloudless and weak aerosol atmosphere***
- ***Inverse models and software development***
- ***Applications of the forward and inverse models to environmental research***

Geometries for radiative transfer calculations

- **Downlooking observation (nadir, slant path)**
  (Radiance, Transmittance, Brightness Temperature)

- **Uplooking observation (from zenith to 90^0)**
  (Radiance, Transmittance, Brightness Temperature)

- **Limb (satellite, balloon)**
  (Radiance, Transmittance, Brightness Temperature)

FIRE-ARMS (Fine InfraRed Explorer of Atmospheric Radiation MeasurementS)
http://remotesensing.ru

Gribanov K.G., Zakharov V.I., Tashkun S.A., Tyuterev Vl.G. A New Software Tool for Radiative Transfer Calculations and its Application to IMG/ADEOS data // JQSRT. - 2001. - Vol. 68. - No.4. - pp. 435-451.

Forward model

Main features:

Spectral range – (0 – 15000 cm^{-1});
HITRAN-2k, HITRAN-2004 database.

- ⇨ ***Geometries:*** *up-looking, down-looking, limb;*
- ⇨ *Line by line high spectral resolution calculations (minimal step size 0.0001 cm^{-1}) + water vapor continuum models (T. Clough) + aerosol absorption (WMO model);*
- ⇨ *Models of line mixing effect in CO_2 and CH_4 bands (J.-M. Hartmann);*
- ⇨ *Convolution of high resolution spectra with ILS functions;*

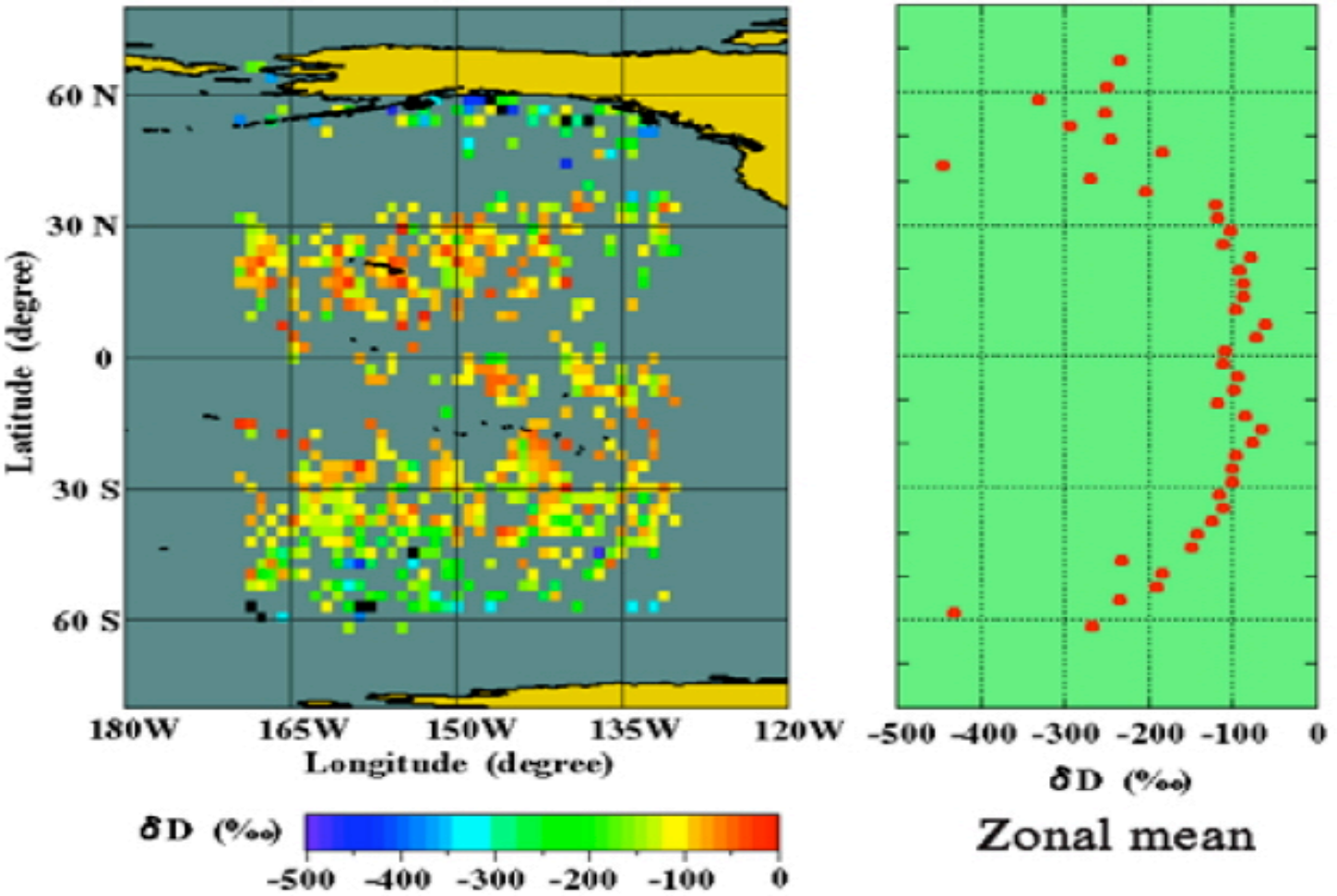
FIRE-ARMS (Fine InfraRed Explorer of Atmospheric Radiation MeasurementS) http://remotesensing.ru

Inverse Models:

- *Optimal estimation method (included into FIRE-ARMS)*
- *Constrained minimization or non-linear least square method (included into FIRE-ARMS)*
- *Singular value decomposition method (included into FIRE-ARMS)*
- *Artificial neural networks and an original models of Institute of Mathematics & Mechanics of Ural Division of RAS (under development)*

Horizontal distribution of retrieved δD values (left) and the zonal mean in 3^0 latitudinal steps (right)

Zakharov V.I., R. Imasu, K.G. Gribanov, G. Hoffmann and J. Jouzel, Latitudinal distribution of deuterium to hydrogen ratio in the atmospheric water vapor retrieved from IMG / ADEOS data // Geophysical Research Letters, v. 31, N12, June 28, 1-4, 2004.

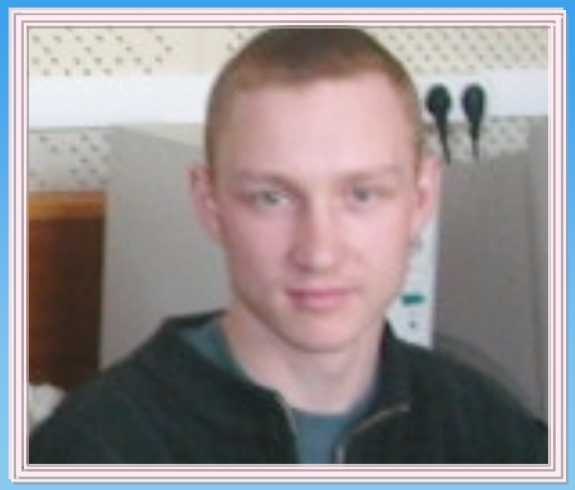


Participation in CASUS project

- *The permafrost Sub-Arctic zone of Western Siberia is significant natural and anthropogenic source of CH_4 emission to the atmosphere. One of prospective methods for global monitoring of methane content in the atmosphere is high resolution spectrometry in thermal infrared from Space. AIRS spectrum data are suitable for the purpose.*

- *Methane horizontal distribution is retrieving over the Siberian area from AIRS/AQUA spectrum data using an originally developed forward/retrieval model, FIRE-ARMS. The method is based on retrieval of atmospheric temperature profile using AIRS clear sky observation spectra in the range of 680 - 800 cm^{-1} and then retrieval of CH_4 content in total atmospheric column using the data in the range of 1290 - 1310 cm^{-1}.*

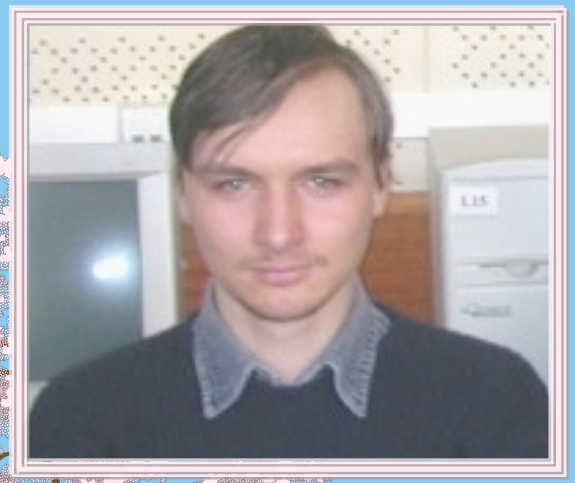
- *Main features of the retrieval scheme and obtained 2D methane distributions in the atmosphere of Sub-Arctic zone of peatland ecosystems of the Western Siberia (60-67N; 60-90E) for summer 2004 and winter 2004-2005 are discussed in this paper.*



INTAS

CASUS project 2004-2006

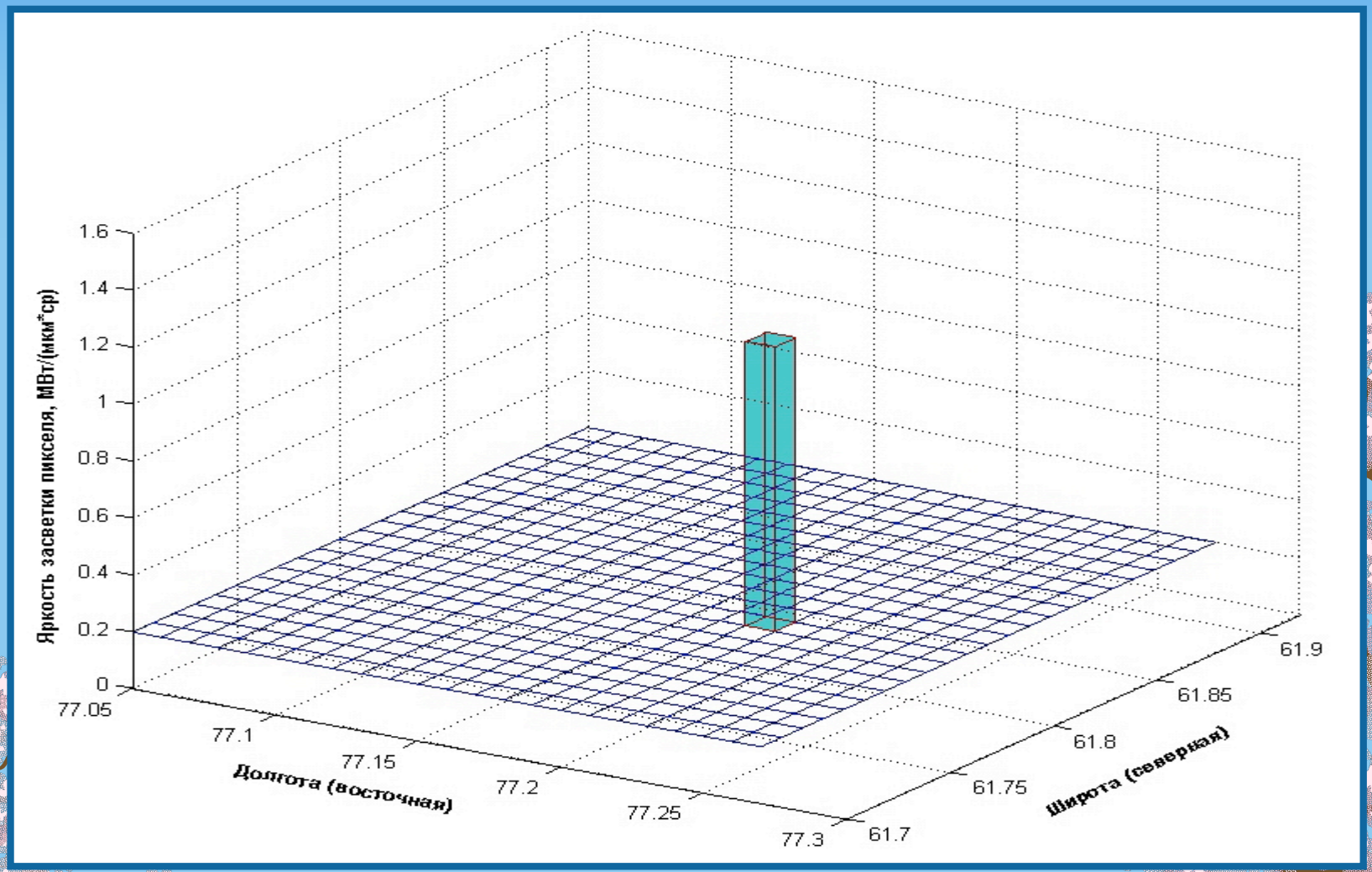
Ural State University Team



There are about 3000 oil-gas flares in the Western Siberia

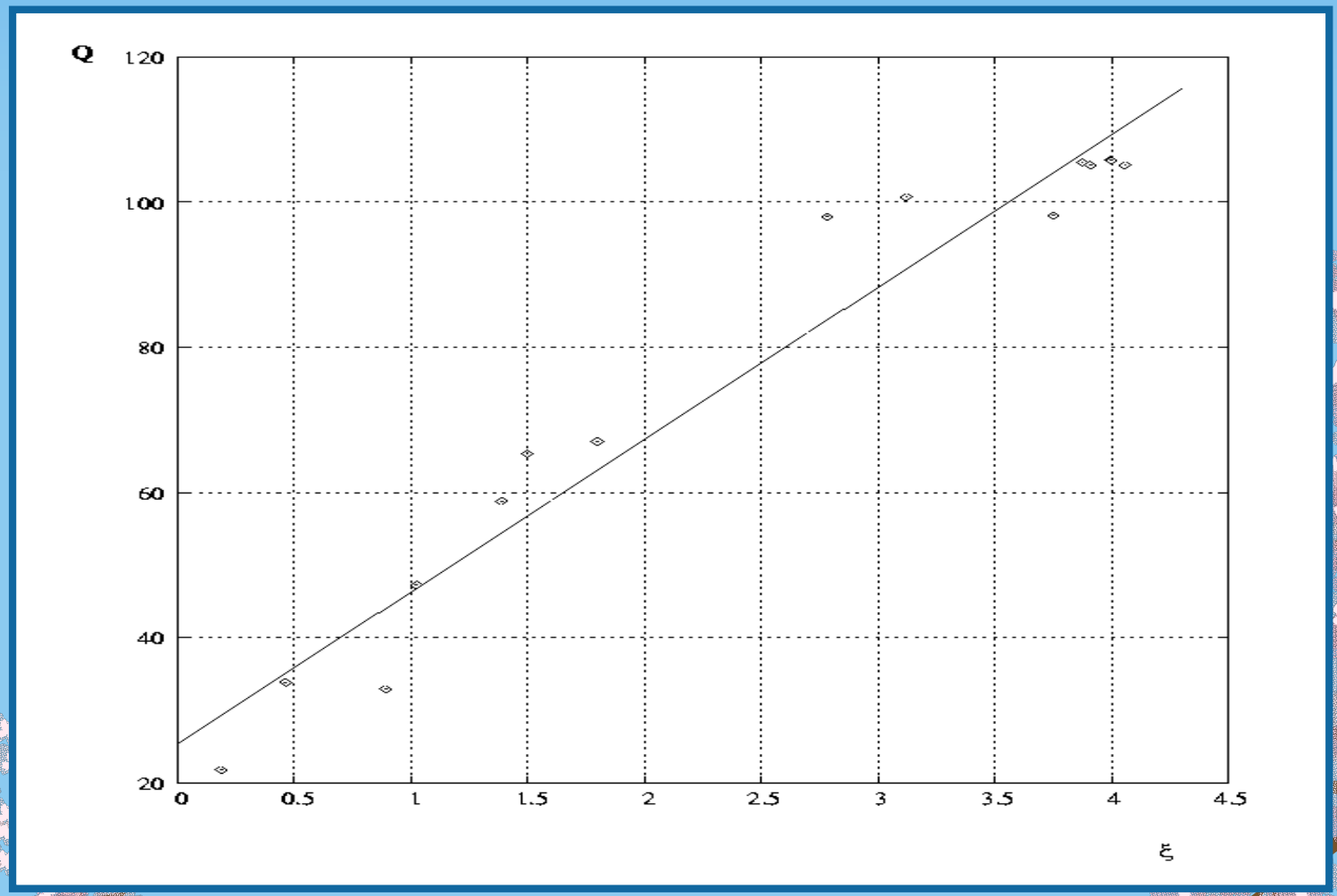
Power of the flare is greater than 200 MW

Extra value of surface radiance recorded by MODIS (3.660-3.840 μm, channel 20) at pixel affected by flare. Location of the flare is around 61.8 N; 77.2 E.



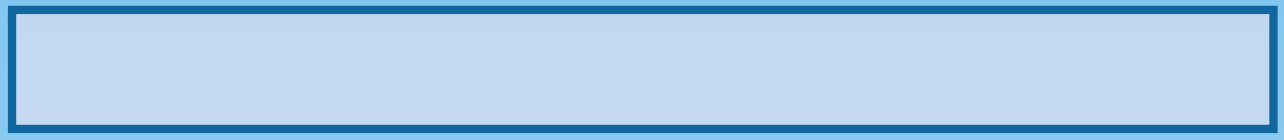
Q – amount of oil-gas combustion in the flare (thousand m^3 / hour);

ξ – extra value of surface radiance observed in 20th channel of MODIS due to the flare affect. August 2004 data.

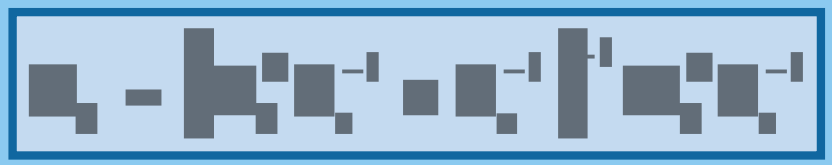


Temperature profile retrieval using high resolution spectrometry from Space. FIRE-ARMS - conventional optimal estimation method (OEM). http://remotesensing.ru

OEM for retrieval of temperature profiles realizes the following iterative scheme of maximum likelihood retrieval (C. Rodgers):

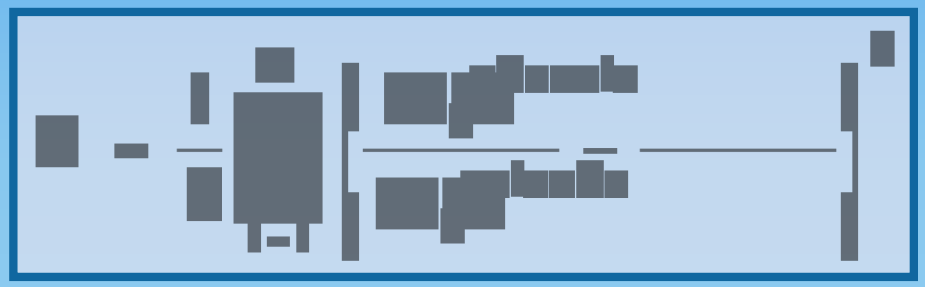


where x_k is a atmospheric temperature profile retrieved in k-th iteration, x_0 is initial guess profile, y is measured spectrum, y_k is spectrum simulated with forward model, K_k is Jacobian of forward model, I is identity matrix. Matrix C_k is a matrix defined in each iteration as:



S_ε is measurement error covariance matrix, S_a is a priori covariance matrix of initial guess profiles .

Methane retrieval using constrained minimization of the target function F by least square method

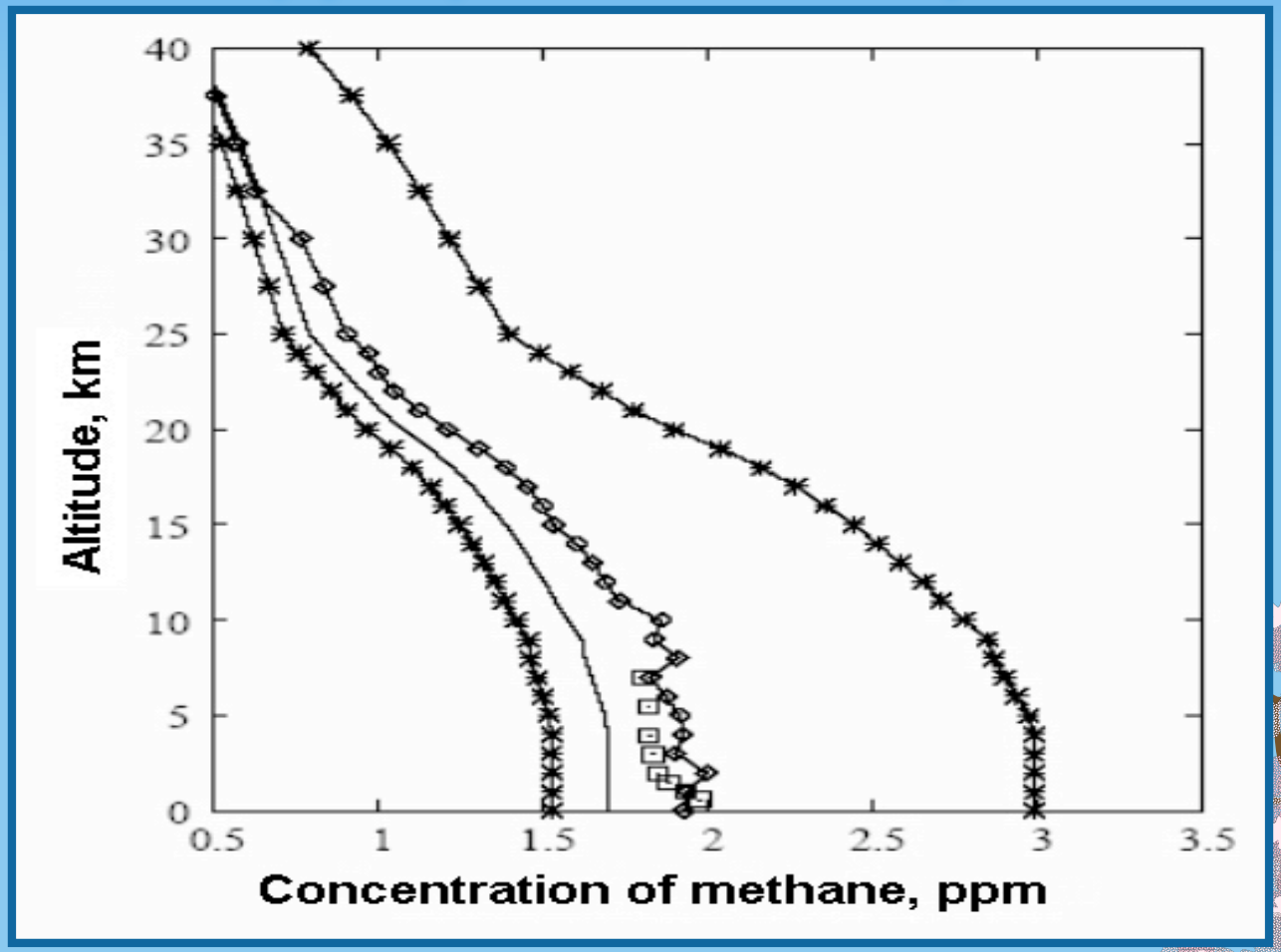


W_i – radiance in i-th channel. M – number of spectral channels taking into account.

Constrains:

Here $a > 0.8$; $b < 2$. $(CH_4)_j$ and $(CH_4)_j^{ref}$ are retrieved and reference concentrations of methane in j^{th} layer of atmosphere.

Example of test retrieval of CH_4 vertical profile in atmosphere of Western Siberia from IMG/ADEOS spectrum observed in summer 1997 using constrained minimization method (line with diamonds).
Initial guess profile (solid), constrains (line with stars), and aircraft measurements (squares) are also shown in this plot.



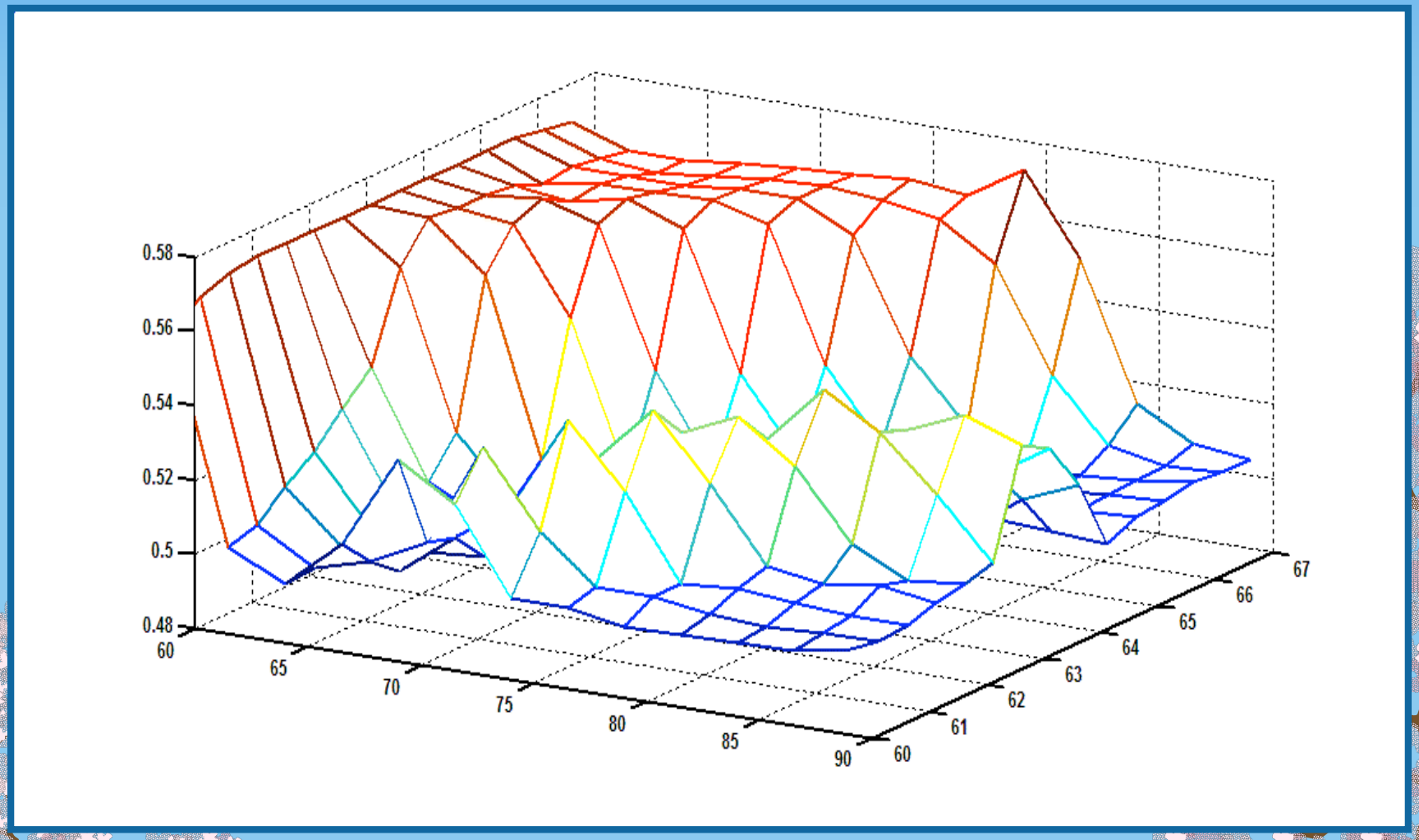
A.Yu. Toptygin, K. G. Gribanov, R. Imasu, W. Bleuten, and V. I. Zakharov
SPIE vol. 5655, p.p. 508 – 514, 2004.

Evaluation of errors of CH_4 retrieval from AIRS spectra

- ***Basically AIRS spectra have good S/N > 100 in the temperature (680 - 800 cm^{-1}) and CH_4 (1290 – 1310 cm^{-1}) channels;***
- ***AIRS spectra in the methane channels are very weakly dependent on water vapor profile within its 500% variations;***
- ***An error analysis was made based on forward simulations of the AIRS spectra using set of sonde measured T and water vapor profiles as well as airplane measured and simulated CH_4 profiles. Noise of AIRS was added to the simulated spectra and then retrieval of the known methane profiles was made again starting from mean references profile.***
- ***The errors of retrieval of methane content in the atmosphere from AIRS spectra in the range of 1298 – 1306 cm^{-1} are determined mainly by error of temperature profile retrieval and error of methane retrieval itself;***
- ***The estimated error of the retrieval of methane content in total atmospheric column using AIRS spectra is around 5%.***

Summer 2004 mean methane content (mole / m^2) in the atmosphere over target area of Western Siberia (60-67N; 60-90E) retrieved from AIRS/AQUA spectra

Winter 2004-2005 mean methane content (mole / m^2) in the atmosphere over target area of Western Siberia (60-67N; 60-90E) retrieved from AIRS/AQUA spectra



A summary regarding AIRS CH_4

K. G. Gribanov, R. Imasu, A. Yu. Toptygin, W. Bleuten and V. I. Zakharov "Method and results of CH_4 content retrieval in the atmosphere from AIRS/AQUA spectra in far IR", Proceedings of ASA2005 Workshop, Reims 2005, France, September 6-8.

- *Method and code for retrieval of CH4 in total atmospheric column from AIRS spectra in thermal IR is developed. A seasonal mean methane distributions in the atmosphere of Sub-Arctic zone of peatland ecosystems of the Western Siberia (60-67N; 60-90E) for 2004-2005 years have been obtained.*
- *Winter mean methane distribution in the atmosphere over target area of Western Siberia retrieved from AIRS/AQUA spectrum data shows: the natural gas and oil production local industry is significant anthropogenic source of methane emission into the atmosphere.*
- *We are going to improve and adapt this code as to be a retrieval component of the GOSAT data analyzing system for retrieving minor constituent concentrations in atmosphere such as methane.*
- *This study is supported by JAXA GOSAT project, European INTAS project CASUS 03-51-6294, and RFBR-Ugra project No. 03-07-96836.*